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Zinc

Acute Toxicity Test of Zinc Shot on Game-farm Mallards

Preliminary Report

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To

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BACKGROUND

As a result of increased recognition of the problems associated with the ingestion of spent lead (Pb) shot by waterfowl, the United States (US) began the phase-in of non-toxic shot regulations in the early 1970s, culminating in a nationwide ban on the use of Pb shot for all waterfowl hunting in 1991. Canada first established non-toxic shot zones in 1991. In 1995, the Canadian government announced intentions to ban the use of Pb shot for the hunting of migratory birds on federal lands in 1996, with implementation of a nationwide ban in 1997 (Canadian Wildlife Service, 1995). Currently, only iron (Fe) and bismuth/tin (Bi/Sn) shot are approved as non-toxic shot in both the US and Canada.

Because Fe shot is harder and lighter in weight and Bi shot is more expensive, as compared with Pb, industry has continued to search for non-toxic alternatives to Pb shot. Zinc (Zn) shot is currently in use as a Pb shot substitute for waterfowl hunting in Great Britain and parts of Europe (W. Shunke, Grillo Werke, pers. commun.). Zinc coatings of less than 0.0002" thickness or less than 1.0% of the weight of the shot pellet are currently approved in the United States (Cyndi Perry, USFWS, pers. commun.). Although lighter in weight than Fe, the greater malleability of Zn makes it a popular alternative to Fe shot in Europe, where thin-walled barrels and expensive shotguns are popular. In addition, Zn shot shells currently cost about the same as Fe and less than Bi. Anticipation of new markets for non-toxic shot has led manufacturers to focus on the development and testing of candidate shot for subsequent approval as non-toxic shot.

The objective of the present study was to conduct the Acute Toxicity Test of Zn shot for Grillo-Werke, Duisburg, Germany, as specified in Canadian Wildlife Service (CWS) guidelines (Environment Canada 1993).

LITERATURE REVIEW

Zinc is an essential element, found in all living organisms and required for many biological processes and optimal health (Walsh et al. 1994; Eisler 1993). Zinc is required for the proper functioning of many enzymes, including those important in regulating the synthesis and catabolic rate of RNA and DNA (Vallee 1959; Prasad 1979).

The primary site of Zn absorption is the small intestine, and is affected by intake level, form ingested, and presence of other elements and compounds in the diet (Underwood 1971). Copper (Cu), calcium (Ca), cadmium (Cd), and phytates decrease the absorption of dietary Zn (Underwood 1971; Eisler 1993; Walsh et al. 1994). Blood Zn levels are reflective of changes in Zn intake; increased dietary Zn intake results in increased whole blood and plasma Zn concentrations (Underwood 1971).

Excretion by way of the feces is an important means of maintaining Zn homeostasis (Underwood 1971; Eisler 1993). Metallothioneins are metal-binding proteins important in mediating intracellular zinc homeostasis by binding excess Zn (Starcher et al. 1980).

Underwood (1971) reported that normal Zn concentrations in various mammalian tissues ranged from 12 to 223 mg/kg DW, with the highest levels found in the prostate. In another study (Prasad 1979), Zn levels in humans and selected domestic mammals varied from 45 to 2330 mg/kg DW; the higher value was from hyperplasic prostate tissue. Eisler (1993) concluded that levels in tissues of birds and mammals were typically < 210 mg/kg DW, and that Zn poisoning usually occurs in birds at liver or kidney concentrations > 2100 mg/kg DW and in mammals when kidney, liver, or pancreas levels exceed 274, 465, and 752 mg/kg DW, respectively.

Many aquatic organisms are sensitive to Zn in various forms, the toxicity of which is

affected by pH, alkalinity, dissolved oxygen level, and temperature (Skidmore 1964; Weatherly et al. 1980). Accounts of Zn poisoning in terrestrial vertebrates have been largely experimental or anecdotal, however, there is growing concern about increased exposure due to anthropogenic sources of Zn. White-tailed deer (*Odocoileus virginianus*), songbirds, small mammals, amphibians, and horses (*Equus caballus*) were affected by emissions from nearby Zn smelters (Beyer et al. 1985, Sileo and Beyer 1985; Beyer 1988), and wildlife can be secondarily impacted through reduced invertebrate prey populations and damage to vegetation.

Commonly reported effects of intake of excessive levels of Zn in terrestrial vertebrates included depressed growth, lowered reproduction, anemia, ataxia, paresis, reduction or cessation of feeding, weight loss, depression, enteritis, diarrhea, pancreatic and/or hepatic histopathology and dysfunction, developmental abnormalities, Cu and Fe deficiencies, high tissue Zn levels, lethargy, liver and/or kidney hypertrophy, internal hemorrhaging, and resorption, softening, or abnormal formation of bone (Underwood 1971; Eisler 1993; Walsh et al. 1994). Metal fume fever resulting from inhalation of Zn oxides produced by industrial processes such as smelting produces fever, tachycardia, dyspnea, and chest pains in humans (Eisler 1993). The interaction between Zn and other metals is complex. Zinc may operate antagonistically to protect an organism from the effects of high levels of other metals or cause deficiencies (e.g., Cu and Fe) and associated maladies, or function synergistically to exacerbate the detrimental effects of high levels of Zn and other elements alone (Eisler 1993). In the right form under the proper conditions Zn can promote or inhibit the growth of tumors, can be mutagenic or inhibit the mutagenic action of certain carcinogens, and can produce teratogenic effects or protect against some teratogens (Eisler 1993). The effects of Zn on immunological systems are unclear (Walsh et al. 1994).

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Poultry are routinely fed excessive levels of Zn to induce molting in order to promote long-term egg production. Although hens can tolerate levels exceeding 8,000 mg Zn/kg diet, this quantity is fatal to chicks. Much lower levels can inhibit growth, suppress immune system function, cause Fe and Cu deficiencies, and impair pancreatic function (see Eisler 1993).

Gasaway and Buss (1972) fed Zn carbonate at levels ranging from 3,000 to 12,000 mg/kg to 7 week-old domestic mallard ducks (*Anas platyrhyncos*). Reductions in food consumption and body weight were associated with dietary Zn levels. Compared with controls, Zn-fed ducks exhibited reductions in pancreas, liver, and gonadal weights, increased adrenal and kidneys weights, increased tissue Zn concentrations, lowered hematocrit and hemoglobin levels, and increased mortality, along with diarrhea and paralysis. Yellowish-red kidneys were the only gross lesions reported.

Eighteen-month-old mallards dosed with 8 No. 6 Zn shot exhibited weight loss, ataxia and paresis (12 of 15 ducks), kidney histopathology (1 duck), high Fe concentrations in livers of affected ducks, and increased mortality (Grandy et al. 1968). The authors suggested that consideration of Zn as a non-toxic shot should be discontinued. In contrast, French et al. (1987) dosed 1 yr-old mallards with either 5 or 10 nearly pure (99.9%) No. 6 Zn shot. After 28 days the authors reported no gross lesions or abnormalities in either dosing group, and no histopathological changes in liver or kidneys of the lower dosing group were noted. The dosed ducks gained weight, exhibited normal liver Fe levels, and increased liver Zn concentrations. The authors stated that Zn-dosed ducks had "markedly better conditioned plumage" than controls, and concluded that Zn shot was an acceptable substitute for Pb shot for hunting waterfowl.

The primary objective of the present study was to determine if Zn shot is toxic to game-

farm mallards under the test conditions specified by the CWS (1993). Thus, our goal was to document any toxic effects. If toxic effects were identified, then it was important to correlate them with concentrations of various elements in tissues. If no toxic effects were demonstrated, the levels of elements, including Zn, would be of lesser importance to the objectives of this study.

METHODS

The Acute Toxicity Study was conducted using 40 female and 40 male wild-type game-farm mallards (*Anas platyrhynchos*), 6 to 8 months of age, purchased from Whistling Wings, Hanover, Illinois. The ducks, reared on a 60-acre lake, were transported from Hanover to Champaign, Illinois, by truck in crates on 7 August 1996.

Upon arrival at the Illinois Natural History Survey's facility in Champaign, the ducks were weighed and randomly assigned to pens, with one duck per pen. Forty ducks (20 females and 20 males) were randomly assigned to one of the 2 treatments; dosed with 6 No. 4 Zn or Fe shot.

The pens are consecutively-numbered, elevated, outdoor, 3.3-foot (1-m) square pens constructed with vinyl-coated, 1-inch (25.4-mm) mesh, 14-gauge wire (see Sanderson et al. 1992 for more details). A 10- x 40-yard pole barn without sides provided a roof over the pens.

Facilities for holding the ducks were inspected by several members of the Laboratory Animal Care Committee, University of Illinois, prior to the study. Committee members also visited the facilities several times during the study. Commercial duck pellets (Heinhold 17% Duck Finisher Pellet, Heinhold Feeds, Inc., Kouts, IN) were provided *ad libitum* during the 3-week acclimatization period. The duck pellets contained a minimum of 17.0% protein. On the date of dosing, the pellets were removed and shelled corn was provided *ad libitum* for the duration of the

study.

The study was begun on 27 August 1996 (Day 0) when the ducks were weighed, bled, and dosed. A small plastic funnel fitted with a plastic tube (3/8 inch [9.5 mm] outside diameter, 9 inches [22.9 cm] long) was inserted down the gullet and into the proventriculus. The tube was kept in a pail of water between dosings to facilitate insertion into the alimentary canal. The shot were poured into the funnel and flushed into the proventriculus with approximately 5 ml of water. Before dosing, the doses (6 No. 4 {0.13" dia.}) of shot were counted, weighed, and placed in individual vials in the laboratory. The type, number, and weight of shot were recorded on the top of each vial and on a computer printout for each duck. At dosing, the shot dose was matched with the corresponding duck.

Blood was collected from a wing vein in heparinized microhematocrit capillary tubes for hematocrit determination and in 2.5-ml syringes fitted with twenty-gauge, 1-inch (25.4-mm) needles to obtain samples to ascertain concentrations of selected elements. The whole blood was injected into 10-ml lithium heparinized Vacutainer^{R} tubes and centrifuged to separate cells and plasma. Body weights were recorded and blood samples collected on Days 0, 15, and 30.

When 24 hematocrit samples (capacity of the centrifuge) had been collected, the hematocrit tubes were centrifuged and read at the site. The tubes were spun for 5 minutes at 11,500 RPM at 13,000-g force.

Whole blood samples were also centrifuged at the site when 12 samples (capacity of the centrifuge) were collected. The tubes were spun for 10 minutes at 3,000 RPM. Plasma was removed with micropipettes and placed in 5-ml non-heparinized Vacutainer^{R} tubes; cells were left in the 10-ml lithium heparinized tubes. As the plasma and cells were separated, the tubes were

placed in metal racks and placed in a refrigerator until transported to freezers at the nearby State Water Survey Laboratory. Samples were stored at -10^0 F until thawed in preparation for chemical analysis.

Detailed behavioral observations were collected each morning (without reference to dosing) and a cursory visit was made in the afternoon to note any changes in severity of signs, process any dead ducks, and ascertain whether any ducks might be candidates for euthanasia. We modified the observations of Grandy et al. (1968) to rank affected individuals as exhibiting mild, moderate, or severe signs as follows:

Mild: signs may not be readily apparent; close observation reveals abnormal gait, with bird at least occasionally picking up it's feet higher than normal when walking or running; may appear slightly lethargic; otherwise may appear normal.

Moderate: signs readily apparent; bird high-stepping as if walking on hot surface; easily noted difficulty in walking or running; trouble maintaining balance when disturbed and regaining it after a fall; may exhibit difficulty folding wings; may appear normal if undisturbed; will attempt to evade on approach.

Severe: bird cannot stand or maintain balance, or can do so only with great difficulty; no or only feeble attempt to evade on approach.

Also noted were the condition of feces (if remarkable), whether each individual had apparently fed (noted by the presence or absence of spilled corn on the duck's tray), and any other noteworthy observations.

On 3 September 1996 (Day 7) all dosed ducks were fluoroscoped by a radiologist at the University of Illinois College of Veterinary Medicine's Large Animal Radiology Laboratory to confirm retention of 6 shot pellets. Ducks were transported to the radiology lab in poultry crates. For fluoroscopy, each bird was restrained in a ½ gallon paper milk carton with a hole cut in the bottom, which allowed the head and neck to protrude. The 4-sided carton was turned 90° to provide dorsal, ventral, and lateral views, which facilitated determination of the number of pellets present. Ducks retaining fewer than 6 pellets were re-dosed to replace the missing pellets.

The Zn shot were provided by W. Shunke of Grillo Werke, Duisburg, Germany. Preliminary analyses of chemical composition of the shot were conducted by the Illinois State Water Survey's Analytical Laboratory, Champaign, Illinois, using Inductively Coupled Argon Emission Plasma Spectroscopy. Fifteen randomly-selected pellets were composed of an average of 97.3% Zn and 4.16% Sn; other elements averaged < 0.1% each. The steel shot were commercially-available pellets sold for reloading shotshells.

All surviving ducks used in the study were weighed and blood was collected from the wing veins as scheduled on 11 September (Day 15) and 26 September 1996 (Day 30). Subsequently, the ducks were euthanized by decapitation and necropsied on Day 30 (with the exception noted below), and the gizzards, livers, kidneys, pancreases, and gonads were excised, weighed, and frozen.

A Veterinary Pathologist necropsied all ducks dying before Day 30 at the University of Illinois' School of Veterinary Medicine's Diagnostic Laboratory. The condition of all major tissues and organs was noted, organs weighed, and specimens preserved for histopathological examination.

The necropsies on the ducks surviving to Day 30 were conducted in the Animal Autopsy Room of the Natural Resources Studies Annex on the campus of the University of Illinois. On Days 30 and 31 the pathologist examined, weighed, and preserved a sample of kidney, liver, pancreas, and gonad for histopathological examination from 10 randomly-selected ducks from each group (sex by dose), with the exception of Zn-dosed females of which < 10 individuals survived. These ducks were euthanized over a period of 2 days (Days 30 and 31) to insure that fresh specimens would be examined. The organs from the remaining ducks were examined, removed, and weighed by project personnel on Day 30. All tissues samples where placed in individual, numbered, plastic bags and stored in the freezer. The frozen organs were moved to the freezer at the State Water Survey and stored with the blood samples until thawed for analysis.

Methods for the elemental analyses, data reports, Quality Assurance, and results of ongoing analyses of tissue element concentrations and post-mortem examinations (gross and histopathological) will be included in the final report.

Statistical Methods

Following CWS guidelines (Environment Canada 1993), sexes were treated separately in comparisons between treatments (Fe- vs. Zn-dosed), except in analyses of shot retention and dissolution in which case the sexes were pooled. All tests were 1-tailed with the exception of analyses of shot retention and dissolution. A probability level of $P \leq 0.05$ was accepted as significant.

Data distributions were assessed by visual examination of frequency histograms superimposed with normal curves, as well as by testing of reported values of skewness, where z = skewness \ SE skewness (Tabachnick and Fidell 1983). Z values greater than $\pm$ 2.58 indicate

a non-symmetrical distribution (P <0.01), and led to additional testing using log-transformed variables. Data transformations were not included in this report because variables were either normally distributed, exhibited only mild to moderate skewness, and /or transformations did not yield a substantial improvement in distribution (i.e. did not reduce, and in some cases exacerbated, skewness) or change the relationship between groups (e.g. yielded the same statistical conclusions regarding the null and alternative hypotheses).

Kaplan-Meier survival functions were calculated using the KM procedure of SPSS (SPSS, Inc. 1996a); all cases were specified as uncensored and functions were compared using the Breslow, or generalized Wilcoxon, test.

The two-sample t test was used to compare differences between treatment groups (Fe- vs. Zn-dosed) except when sample size for either group was ≤ 5, in which case we employed Mann-Whitney U testing; these tests were available through the T TEST and NPAR TESTS procedures of SPSS (SPSS Inc. 1996b). The two-sample t test is robust to all but the most severe departures from normality (Zar, 1984). For one-tailed non-parametric testing, $U^1 = n_1 n_2$ - U. (Zar 1984). For parametric testing, homogeneity of variance between groups was assessed with Levene's test; pooled variances and adjusted degrees of freedom were used when significant heteroscedasticity was detected (SPSS, Inc. 1996c). Coefficient of variation was calculated as standard deviation / mean (Zar 1984).

RESULTS AND DISCUSSION

Survival

All Fe-dosed ducks survived to Day 30/31, when the ducks were euthanized. Sixteen of 20 (80%) female, 9 of 20 (45%) male, and 25 of all 40 (62.5%) Zn-dosed ducks died prior to Day 30 (three of these individuals were euthanized after being found on their backs and unable to right themselves). Mortality in Pb-dosed mallards generally approaches or reaches 100% (Sanderson and Irwin 1976; Sanderson et al. 1992; Sanderson et al. 1996). Grandy et al. (1968) reported 20% mortality to 30 days in 15 male mallards dosed with 8 No. 6 Zn shot, and Gasaway and Buss (1972:1114) indicated that "severe mortality occurred after 30 days", with 92% mortality to 60 days, in ducks fed 3,000 to 12,000 mg/kg Zn carbonate in their diet. In contrast, French et al. (1987) found no mortality to 28 days in mallards dosed with 5 or 10 pure (99.9%) No. 6 Zn shot pellets. Comparisons of mortality across studies should be interpreted carefully, as survival rates differ with sex, age, dosing levels, shot composition, length of studies, rate of voiding of shot, and diet.

In the present study, survival in male Zn-dosed ducks averaged 23 days, and ranged from 9 to 30 days. Survival rates differed between Zn- and Fe-dosed male ducks ($X^2_{0.05,1}$= 11.24; $P <$ 0.001). Survival in female Zn-dosed ducks averaged 18 days, and ranged from 5 to 30 days. Survival rates differed between Zn- and Fe-dosed female ducks ($X^2_{0.05,1}$= 25.24; $P < 0.0001$).

Survival rates did not differ between male and female Zn-dosed ducks ($X^2_{0.05,1}$= 3.21; $P = 0.07$). Similarly, Sanderson et al. (1996) found no difference in survival times between sexes in Pb-dosed mallards. Mean survival times in our study were similar to the 20 days reported by Grandy et al. (1968) for Zn-dosed ducks. The shortest survival time for an individual duck in the

current study was 5 days, which is comparable to 4 days in a mallard dosed with 8 No. 2 Pb shot (Sanderson et al. 1992).

Behavioral Abnormalities

Signs of zinc toxicosis observed were consistent with Grandy et al. (1968) and/or Gasaway and Buss (1972), which included ataxia, paresis, reduction or cessation of food intake, and severe anemia (see below). Behavioral signs of Zn toxicosis were first noted in 9 ducks (7 females) on Day 4 of the experiment. By Day 15, 32 of 40 (80%) Zn-dosed ducks had exhibited at least mild (>1 observation day) signs. Mortality first occurred on Day 5 (1 female) before any signs were noted in that animal. Grandy et al. (1968) reported that one of the Zn-dosed ducks in their study died without exhibiting any signs.

Thirty-five of 40 (87.5%) Zn-dosed ducks exhibited behavioral signs during the course of the experiment. Of these, 25 (71%) were ranked as moderate or severe at some point over the 30-day period. Grandy et al. (1968) detected behavioral anomalies in 12 of 15 (80%) male mallards dosed with 8 No. 6 Zn shot. In their study of the effects of dietary Zn carbonate on mallards, Gasaway and Buss (1972) noted severe paralysis after 20 days, with the onset being most rapid in the group receiving the lowest dosage.

Zinc-dosed ducks typically exhibited a reduction and ultimately cessation of feeding within days of showing moderate signs of toxicosis. Five ducks (3m/2f) survived the experiment without displaying any behavioral signs. All animals ranked only with mild behavioral signs survived to Day 30, whereas only 2 ranked with moderate signs at some point survived to the end of the experiment. Some Zn-dosed ducks went through periods of improvement and deterioration over the course of days or even hours. No animals showing behavioral abnormalities completely

recovered from the effects of Zn-intoxication over the course of the experiment. Grandy et al. (1968) reported that 1 of 3 ducks retaining shot to the end of their study showed no signs of intoxication, whereas another exhibited signs for 5 days but had "fully recovered" by 30 days.

The severely-anemic condition of Zn-dosed animals became apparent through pallor of the oral cavity (and documented by hematocrits). Dark or bright green feces were noted within 1 or 2 days of dosing. Five ducks passed blood with their feces, however, this persisted to death only in 1 female. Another duck, also a female, was noted as having passed blood on 1 occasion, and exhibited no other signs throughout the experiment.

Other signs of Zn toxicosis noted included diarrhea, excreta having a foul odor, a drooping or tucked tail, clacking of the bill and associated uncontrolled movements of the head, and evasive behavior often associated with diseased waterfowl (e.g., would try to hide under the water pipe in their cage).

Body Weight

Ducks gained weight (for males, x = 60 g.; for females x = 40 g.) during the 21-day acclimatization period. Both male and female Zn-dosed ducks lost weight, on average, between Days 0 and 15, whereas males gained weight between Days 15 and 30 (Table 1). These data included body weights for ducks that died between Day 0 and 15 and Day 15 and 30, respectively. Variability increased over time, presumably due to weight loss in ducks experiencing moderate to severe Zn-toxicosis, as compared with ducks exhibiting no or mild signs. Male and female Fe-dosed ducks showed little or no change in weight from Day 0 to 15 and from Day 15 to 30. This pattern was similar to that reported by Sanderson et al. (1995) for Bi-, Fe-, and 0-dosed mallards. Variability in weight in Fe-dosed ducks did not change remarkably throughout our study

(Table 1).

Male Zn-dosed ducks as a group experienced greater weight loss (expressed as percentage body weight change) between Days 0 and 15, compared with Fe-dosed males (Table 2). These differences in mean percent weight change were significant ($t_{0.05\,(1)20}$= -4.0, $P < 0.001$).

Mean percent weight loss in male Zn-dosed ducks surviving less than 15 days was considerably greater than in those which survived at least 15 days. These differences in mean percent weight change were significant ($U'_{0.05(1),5,15}$= 57, $P = 0.05$).

Females in both dosing groups lost weight between Days 0 and 15 (Table 3). The mean percent weight lost in Zn-dosed females between Days 0 and 15 or death (if <15 days) was marked and greater than in Fe-dosed females ($t_{0.05(2)21}$= - 6.0, $P< 0.001$). Weight loss in Zn-dosed females surviving 15 days and those surviving <15 days was similar ($U'_{0.05(1),4,14}$= 27, $P > 0.10$).

Male Zn-dosed ducks lost 16.5% of their body weight, on average, to Day 30 or death (if <30 days), whereas Fe-dosed males lost only 2.4% percent (Table 4). This difference in mean percent weight change was significant ($t_{0.05(1)20}$= - 3.9, $P <0.001$). Male Zn-dosed ducks surviving to Day 30 lost a small amount of weight, as a group, whereas those surviving < 30 days lost considerable proportion of body weight between Day 0 and death. The difference in mean percent weight change between these 2 groups was significant ($t_{0.05(1),11}$= 11.2, $P <0.001$).

Zn-dosed females experienced considerable weight loss, on average, between Day 0 and Day 30 or death (Table 5). Fe-dosed females as a group lost a smaller percentage of their body weight from the start to the end of the experiment. The difference in mean percent weight change

between these dosing groups was significant ($t_{0.05(1),19}$= -6.7; P <0.001).

Female Zn-dosed ducks that died prior to Day 30 lost more than one third of their body weight between Day 0 and death (Table 5). This mean loss in body weight was considerably greater than in Zn-dosed females surviving to Day 30 ($U'_{0.05(1),4,14}$= 64; P < 0.001).

Mean percent loss of body weight in our study was as high as 33% and 40% for Zn-dosed males and females, respectively, which died prior to Day 30. Weight loss in Zn-dosed ducks that survived to Day 30 was similar to weight loss in Fe-dosed ducks, all of which survived to Day 30. In their review of lead poisoning, Sanderson and Bellrose (1986) reported that mallards dying of chronic Pb-poisoning typically lose 40-60% of their body weight, whereas those dying of acute Pb-poisoning may lose little weight. Mean weight loss to 30 days in mallards fed Zn carbonate along with a chicken developer - turkey finisher diet ranged from 17 to 44%, with females losing a greater proportion of body weight than males (Gasaway and Buss 1972). Grandy et al. (1968) reported that mean weight loss in male mallards dosed with 8 No. 6 Zn pellets and placed on a corn and grit diet was 33% for 3 birds that died, and 22% in those surviving 30 days. In contrast, French et al. (1987) found that mallards dosed with 5 or 10 No. 6 Zn shot pellets and kept on a varied diet of small grains, commercial feed, and grit gained weight. Weight loss in Pb and Zn dosing experiments has been attributed to a reduction or cessation of feeding.

Retention and Dissolution of Shot

All of the Fe-dosed ducks, and 36 of 40 (90%) Zn-dosed ducks retained all 6 shot to 3 September 1996 (Day 7) when they were fluoroscoped. Of the Zn-dosed ducks, one male and one female each had 2, one female had 3, and one male had 5 shot in their gizzard. These ducks were re-dosed to replace the missing pellets.

After necropsy, the contents of the gizzard, proventriculus, and a short length of intestine were examined for shot. The linings of the gizzard in Zn-dosed ducks which died or were euthanized during the experiment were stained a walnut-brown color and were brittle. Gizzard linings in Fe-dosed and Zn-dosed ducks surviving to Day 30 were stained yellow (with the exception of one Zn-dosed which was green) and normal in texture. According to Sanderson and Bellrose (1986:8), the gizzard lining of Pb-poisoned waterfowl is often "dark, soft, decayed, easily eroded, inflamed, corroded, and incomplete". Droual et al. (1991) documented severe gizzard erosion in a gray-headed chachalaca (*Ortalis cinereiceps*) which had ingested a copper-plated Zn penny.

The recovered Fe and Zn shot recovered from the gizzard differed in appearance. The Fe shot were generally round, with pits or empty spaces on the surface. The Zn shot recovered from ducks that died prior to Day 30 were round with a dimpled surface, reminiscent of a golf ball. Most of the Zn shot recovered from ducks surviving to Day 30 were greatly reduced in size and worn smooth, although some were fragmented.

The gizzards of 8 Zn-dosed ducks contained fewer than 6 shot, however, pellets recovered from 4 individuals that survived to Day 30 were worn to tiny pellets. These ducks retained 2, 3, 4, and 5 pellets, respectively. Because of the small size of the remaining shot, and the high retention rate observed, we assumed that the other pellets had completely dissolved. Given this assumption, we accounted for a relatively high proportion of the dosed shot (Table 6). Although the mean number of shot retained was higher for Fe-dosed than for Zn-dosed ducks, this difference was not significant ($t_{0.05(2),78} = -0.71$, $P = 0.48$). Retention rates were slightly lower than those reported by Sanderson et al. (1995) for Bi- (100%) and Fe-dosed (98.8%) mallards.

Grandy et al. (1968) found that only 3 of 15 Zn-dosed mallards retained any shot to 30 days, with none retaining the original dose of 6 pellets. French et al. (1987) reported retention rates of 98% and 50%, respectively, in mallards dosed with 5 or 10 No. 6 Zn shot pellets.

For ducks that retained 6 shot, the percentage of the original shot weight that had dissolved was slightly higher in Fe-dosed than in Zn-dosed ducks (Table 6); this difference was not significant ($t_{0.05(2),41}$= -0.567, P = 0.57). The percent of the original shot weight dissolved ranged from 9% to 100% (< 1.0 % remained) in Zn-dosed ducks and 36% to 76% in Fe-dosed ducks. Dissolution rates (g/day) were identical in these 2 groups.

In ducks that retained 6 shot and survived to Day 30 the mean percentage of the original shot weight dissolved was significantly higher in Zn-dosed, as compared with Fe-dosed, ducks (Table 6) ($t_{0.05(2),49}$ = 5.59, P= <0.001). The percentage of shot weight dissolved ranged from 71% to 100% (<1.0% remained) in Zn-dosed ducks. The dissolution rate was also higher in Zn-dosed compared with Fe-dosed ducks ($t_{0.05(2),49}$= 11.10, P <0.001). The dissolution rate ranged from 0.02 to 0.03 g/day in Zn-dosed and from 0.01 to 0.02 g/day in Fe-dosed ducks. Mean absorption rates were 0.009 and 0.01 g/day, respectively, in mallards dosed with 5 or 10 No. 6 pure Zn pellets (French et al. 1987).

We detected no differences (P> 0.05) between the sexes for the mean number of shot retained, percent of original shot weight dissolved, or dissolution rate. Shot dissolution ranged from 38.2% to 96.5% of the original dose in Bi-dosed ducks, with no differences between the sexes, and from 38.0% to 89.6% in Fe-dosed ducks, with females dissolving a greater proportion of the original shot weight than males (Sanderson et al. 1995). The authors attributed the higher dissolution to increased food consumption by females in preparation for the breeding season.

Organ Weights

Liver

Mean liver weight did not differ between Zn- and Fe-dosed males ($t_{0.05(1)38}$ = -0.91, P> 0.10) and represented similar proportions of total body weight in both groups ($t_{0.05(1)22}$ = 1.31, P> 0.10) (Table 7). Liver weight in Zn-dosed males which died prior to Day 30 was greater than in those surviving to Day 30 ($t_{0.05(1)18}$ = -2.44, P< 0.05). The livers of Zn-dosed males surviving <30 days represented nearly twice the proportion of total body weight as compared with ducks surviving to Day 30 ($t_{0.05(1)18}$ = -5.61, P< 0.0001).

Females exhibited a similar pattern as in males for liver weights. Mean liver weight did not differ between Zn-dosed and Fe-dosed females ($t_{0.05(1)28}$ = -1.23, P> 0.10), however, liver weight as a percentage of body weight was greater in Zn-dosed vs. Fe-dosed females ($t_{0.05(1)22}$ = 2.29, P< 0.05) (Table 7). Mean liver weight did not differ between female Zn-dosed ducks that survived to Day 30 and those that did not ($U^1_{0.05(1)4,16}$ = 46, P> 0.10), however, liver weight represented a greater proportion of body weight in those that died prior to Day 30 ($U^1_{(0.05)1,4,14}$= 64, P< 0.0005).

Pancreas

Mean pancreas weight was significantly greater ($t_{0.05\,(1),34}$ = -6.1, P <0.001), and represented a greater proportion of total body weight ($t_{0.05\,(1),38}$ = -3.2, P <0.01) in Fe- than in Zn-dosed males (Table 8). Pancreas weight did not differ between Zn-dosed males surviving to Day 30 and those that did not ($t_{0.05\,(1),18}$ = 0.70, P >0.10); however, the pancreas represented a greater proportion of body weight in those that died prior to Day 30 ($t_{0.05\,(1),18}$ = -2.10, P <0.05).

Pancreas weights averaged greater ($t_{0.05\,(1),38}$ = -7.3, P <0.001) and represented a larger

proportion of body weight ($t_{0.05\,(1),36}$ = -3.9, P <0.001) in Fe- than in Zn-dosed females (Table 8). Pancreas weight did not differ between Zn-dosed females surviving to Day 30 and those that did not ($U^{1}_{0.05(1)4,16}$= 34, P = 0.45), however, the pancreas represented a greater proportion of body weight in those that died prior to Day 30 ($U^{1}_{0.05(1)4,16}$= 53, P < 0.05).

Kidneys

Kidney weights averaged greater ($t_{0.05(1)24}$ = 3.45, P< 0.01) and represented a higher proportion of total body weight ($t_{0.05(1)20}$ = 4.12, P< 0.001) in Zn- than Fe-dosed males (Table 9). Kidney weights in Zn-dosed males surviving 30 days averaged less than in ducks that died prior to Day 30 ($t_{0.05(1)18}$ = -5.10, P< 0.001). The kidneys of Zn-dosed males surviving <30 days represented twice the proportion of total body weight as compared with ducks surviving to day 30 ($t_{0.05(1)18}$ = -12.84, P< 0.0001).

Mean kidney weight was greater in Zn- than in Fe-dosed females ($t_{0.05(1)31}$ = 3.2, P< 0.01), and accounted for a greater proportion of body weight in the former ($t_{0.05(1)20}$ = 5.92, P< 0.001) (Table 9). Kidney weights in Zn-dosed females surviving to Day 30 averaged less than in those that died prior to 30 days ($U^{1}_{0.05(1)4,16}$ = 63, P= 0.0005) (Table 9). The kidneys of Zn-dosed females surviving <30 days represented more than twice the proportion of total body weight as compared with ducks surviving to day 30 ($U^{1}_{(0.05)1,4,14}$= 56, P= 0.0005).

Gonads

Mean gonadal weight ($t_{0.05(1)38}$ = -0.52, P> 0.25) and the proportion of body weight accounted for by the gonads ($t_{0.05(1)38}$ = -0.62, P> 0.25) did not differ between male Zn- and Fe-dosed ducks (Table 10). The gonads were heavier ($t_{0.05(1)10}$ = 3.17, P< 0.01) and represented a much greater proportion of body weight ($t_{0.05(1)10}$ = 3.40, P< 0.01) in Zn-dosed males surviving

30 days, as compared with those that died prior to Day 30. Mean gonadal weight did not differ between Fe-dosed and Zn-dosed males surviving to Day 30 ($t_{0.05(1)29} = 0.98$, $P > 0.10$).

Mean gonadal weight ($t_{0.05(1)38} = -1.42$, $P > 0.05$) and the proportion of body weight accounted for by the gonads ($t_{0.05(1)36} = -0.97$, $P > 0.10$) did not differ between female Zn- and Fe-dosed ducks (Table 10). Although the gonads were heavier ($U^1_{0.05(1),\,4,16} = 52$, $P < 0.05$) in Zn-dosed females surviving 30 days, the contribution of the gonad to body weight did not differ ($U^1_{0.05(1),\,4,16} = 41$, $P > 0.10$), as compared with those that died prior to Day 30.

Gizzards

Gizzard weights were greater ($t_{0.05(1)23} = -3.50$, $P = 0.001$) and accounted for a greater proportion of body weight ($t_{0.05(1)37} = -2.10$, $P = 0.05$) in Fe-dosed as compared with Zn-dosed males (Table 11). Mean gizzard weight ($t_{0.05(1)13} = 8.4$, $P < 0.001$) and gizzard weight as a percentage of body weight ($t_{0.05(1)18} = 4.10$, $P < 0.001$) were greater in Zn-dosed males surviving 30 days than in those that did not.

The same pattern was apparent in females, with gizzard weights averaging greater ($t_{0.05(1)38} = -6.7$, $P < 0.001$) and accounting for a larger proportion of body weight ($t_{0.05(1)36} = -4.1$, $P < 0.001$) in Fe-dosed as compared with Zn-dosed ducks (Table 11). Similarly, mean gizzard weight ($U^1_{0.05(1)4,16} = 64$, $P < 0.001$) and gizzard weight as a percentage of body weight ($U^1_{0.05(1)4,14} = 49$, $P < 0.05$) were greater in Zn-dosed females surviving to Day 30 than in those that did not.

Discussion of Organ Weights

The organs of Pb-poisoned waterfowl may be reduced or enlarged at death, depending on the nature of the toxicosis (see Sanderson and Bellrose 1986:10-11). In the present study the

liver, kidney, and pancreas of Zn-dosed ducks that died as a result of Zn intoxication increased in proportion to total body weight. The kidneys of Zn-dosed ducks were heavier, and the pancreases lighter, as compared with Fe-dosed ducks. Gasaway and Buss (1972) found that ducks fed dietary Zn experienced significant reductions in the weight of the pancreas, liver, and gonad, compared with controls, whereas the kidneys represented a larger proportion of body weight. Zee et al. (1985) noted liver and kidney hypertrophy in a captive Nicobar pigeon (*Caloenas nicobarica*) that had ingested Zn fragments.

Although we detected no significant differences in gonadal weight between Zn- and Fe-dosed ducks, the gonads of Zn-dosed animals dying prior to Day 30 were smaller (esp. in males) than in those that survived 30 days. Similarly, the gizzards of ducks that succumbed to Zn toxicosis were smaller than Zn-dosed ducks that survived. Gasaway and Buss (1972) suggested that Zn-mediated retardation of gonadal development could impact breeding success, however, it is likely that some of the "reduction" (or lack of increase) in organ weights in their study and ours is attributable to the younger age of those that died before the end of the experiments.

Hematocrit

Hematocrits increased, on average, in Fe-dosed males over the course of the study, and decreased slightly in Fe-dosed females from Days 0 to 15, before increasing between Days 15 and 30 (Table 12). Mean hematocrit values decreased in surviving male and female Zn-dosed ducks between Days 0 and 15, then increased between Days 15 and 30. For male Zn-dosed ducks, mean hematocrit at Day 30 was greater than at Day 0.

Variability in hematocrits was highest at Day 15, presumably due to severe anemia in ducks experiencing moderate to severe Zn toxicosis. Of those Zn-dosed ducks surviving to Day

30, 8 (1 female), 8 (1 female), and 7 (all males) individuals exhibited increased hematocrits between Days 0 and 15, 15 and 30, and 0 and 30, respectively.

Hematocrits decreased by an average of nearly 9% in Zn-dosed male mallards, and increased slightly in Fe-dosed males, between Days 0 and 15 (Table 13). These differences in mean percent change in hematocrits were significant ($t_{(0.01),\,15} = -1.9$, $P < 0.05$). Individual values ranged from -63.0% to 12.5% and -4.4% to 10.4% in Zn- and Fe-dosed males, respectively.

Both Zn- and Fe-dosed male mallards experienced similar ($t_{(0.01),\,29} = 1.1$, $P > 0.10$) increases in hematocrits (expressed as mean percent change in hematocrit) between Days 0 and 30 (Table 14). Individual values ranged from -2.2% to 17.5% and -4.3% to 17.5% in Zn- and Fe-dosed males, respectively.

Hematocrit values decreased between Days 0 and 15 in both Zn- and Fe-dosed females though this decrease in hematocrits (expressed as percent change in hematocrit) was much greater in Zn-dosed female mallards surviving to 15 days (Table 15) ($t_{0.01,13} = -4.3$, $P < 0.001$). Individual values ranged from -56.5% to 6.7% and -10.6% to 14.0% percent in Zn- and Fe-dosed females, respectively.

Zn-dosed female mallards surviving to Day 30 experienced a slight decline, on average, in hematocrits between Days 0 and 30, whereas mean percent change in hematocrits was positive in Fe-dosed females (Table 16). This difference between dosing groups was not significant ($U^{1}_{(0.01),\,4,20} = 58$, $P = 0.10$). Individual values ranged from -12.2% to 7.3% and -6.5% to 20.9% in Zn- and Fe-dosed females, respectively

Severe anemia is common in Pb-poisoned waterfowl (Sanderson and Bellrose 1986), as well as in Zn-intoxicated vertebrates (Underwood 1971; Eisler 1993; Walsh et al. 1994). Anemia

resulting from Zn toxicosis has been attributed to associated Cu and Fe deficiencies. Although Gasaway and Buss (1972) noted no remarkable reduction in hematocrits until day 30 in mallards fed Zn carbonate, we documented a considerable reduction in mean hematocrit values in both sexes at Day 15. This change can be attributed to the large number of ducks experiencing Zn toxicosis in our study.

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Table 1 . Mean body weight ± S.E. (CV) of 6-8 month-old male and female game-farm mallards dosed with 6 No. 4 Zn or Fe shot.[a]

Dose	Sex	Mean Body Weight (Kg) Day 0	Day 15[b]	Day 30[c]
Zn	M	1.16 ± 0.02 (0.09)	0.99 ± 0.04 (0.17)	1.02 ± 0.05 (0.18) (n= 15)
	F	1.04 ± 0.02 (0.09)	0.71 ± 0.04 (0.25) (n= 18)	0.71 ± 0.05 (0.25) (n= 13)
Fe	M	1.15 ± 0.02 (0.07)	1.13 ± 0.02 (0.08)	1.13 ± 0.02 (0.07)
	F	1.03 ± 0.02 (0.09)	0.98 ± 0.02 (0.09)	0.97 ± 0.02 (0.08)

[a] n= 20 unless otherwise specified
[b] includes ducks surviving < 15 days
[c] includes ducks that survived > 15 and < 30 days

Table 2. Mean percent body weight change ± SE (CV) between Days 0 and 15 in 6-8 month old, male game-farm mallards dosed with 6 No. 4 Zn or Fe shot.[a]

Dose	Percent Change Day 0 - 15
Zn	- 14.8 ± 3.2 (1.0)
Fe	- 1.9 ± 0.6 (1.4)
Zn[b]	- 10.6 ± 3.7 (1.4) (n= 15)
Zn[c]	- 27.4 ± 1.3 (0.1) (n= 5)

[a] n= 20 unless otherwise specified
[b] Zn-dosed ducks surviving at least 15 days
[c] Zn-dosed ducks surviving < 15 days

Table 3. Mean percent body weight change ± SE (CV) between Days 0 and 15 in 6-8 month old, female game-farm mallards dosed with 6 No. 4 Zn or Fe shot.[a]

Dose	Percent Change Day 0 - 15
Zn	- 30.9 ± 4.2 (0.6) (n= 18)
Fe	- 4.6 ± 1.4 (1.3)
Zn[b]	- 30.1 ± 5.3 (0.7) (n= 14)
Zn[c]	- 33.5 ± 3.2 (0.2) (n= 4)

[a] n= 20 unless otherwise specified
[b] Zn-dosed ducks surviving at least 15 days
[c] Zn-dosed ducks surviving < 15 days

Table 4. Mean percent body weight change ± SE (CV) between Days 0 and 30 in 6-8 month old, male game-farm mallards dosed with 6 No. 4 Zn or Fe shot.[a]

Dose	Percent Change Day 0 - 30
Zn	-16.5 ± 3.6 (1.0)
Fe	- 2.4 ± 0.6 (1.1)
Zn[b]	- 3.2 ± 1.0 (1.1) (n= 11)
Zn[c]	- 32.8 ± 2.5 (0.2) (n= 9)

[a] n= 20 unless otherwise specified
[b] Zn-dosed ducks surviving to 30 days
[c] Zn-dosed ducks surviving < 30 days

Table 5. Mean percent body weight change ± SE (CV) between Days 0 and 30 in 6-8 month old, female game-farm mallards dosed with 6 No. 4 Zn or Fe shot.[a]

Dose	Percent Change Day 0 - 30
Zn	- 31.9 ± 3.8 (0.5) (n= 18)
Fe	- 5.9 ± 1.0 (0.7)
Zn[b]	- 4.8 ± 1.8 (0.8) (n= 4)
Zn[c]	- 39.7 ± 1.6 (0.2) (n= 14)

[a] n= 20 unless otherwise specified
[b] Zn-dosed ducks surviving to 30 days
[c] Zn-dosed ducks surviving < 30 days

Table 6. Shot retention and dissolution rate in game-farm mallards (sexes combined) dosed with 6 No. 4 Zn or Fe shot.

Dose	Total Shot Retained	Mean Number Shot Retained	Mean % Loss Shot Weight	Dissolution Rate (g/day)
All Ducks				
Fe	235/240 (97.9%)	5.88	--	--
Zn	231/240 (96.3%)	5.78	--	--
All Ducks retaining 6 shot				
Fe (n=36)	--	--	56.3	0.017
Zn (n=36)	--	--	53.3	0.017
All Ducks retaining 6 shot and surviving to Day30				
Fe (n=36)	--	--	53.3	0.017
Zn (n=15)	--	--	88.1	0.022

Table 7. Mean ± SE (CV) weight of liver and the mean percentage it contributed to total body weight in game-farm mallards dosed with 6 No. 4 Zn or Fe shot[a]

Sex	Dose	Mean Weight (g)	Mean % of Body Weight
M	Zn[b]	16.8 ± 1.2 (0.3)	1.8
M	Fe	18.0 ± 0.5 (0.1)	1.6
F	Zn[b]	15.3 ± 1.2 (0.3)	2.1 (n= 18)
F	Fe	16.9 ± 0.6 (0.2)	1.8
M	Zn_{30}[c]	14.5 ± 0.9 (0.2) (n=11)	1.3 (n=11)
M	$Zn_{<30}$[d]	19.7 ± 2.0 (0.3) (n= 9)	2.5 (n= 9)
F	Zn_{30}[c]	12.6 ± 0.2 (0.0) (n= 4)	1.3 (n= 4)
F	$Zn_{<30}$[d]	16.0 ± 1.4 (0.4) (n= 16)	2.3 (n= 16)

[a]n= 20 for each group unless otherwise specified
[b]includes Zn-dosed ducks surviving < 30 days
[c]Zn-dosed ducks surviving 30 days
[d]Zn-dosed ducks surviving < 30 days

Table 8. Mean ± SE (CV) weight of pancreas and the mean percentage it contributed to total body weight in game-farm mallards dosed with 6 No. 4 Zn or Fe shot[a]

Sex	Dose	Mean Weight (g)	Mean % of Body Weight
M	Zn[b]	1.8 ± 0.1 (0.3)	0.19
M	Fe	2.7 ± 0.1 (0.1)	0.24
F	Zn[b]	1.3 ± 0.1 (0.3)	0.1 (n= 18)
F	Fe	2.4 ± 0.1 (0.2)	0.3
M	Zn_{30}[c]	1.9 ± 0.2 (0.3) (n=11)	0.17 (n=11)
M	$Zn_{<30}$[d]	1.7 ± 0.2 (0.3) (n= 9)	0.22 (n= 9)
F	Zn_{30}[c]	1.3 ± 0.0 (0.1) (n= 4)	0.1 (n= 4)
F	$Zn_{<30}$[d]	1.4 ± 0.1 (0.4) (n= 16)	0.2 (n= 16)

[a]n= 20 for each group unless otherwise specified
[b]includes Zn-dosed ducks surviving < 30 days
[c]Zn-dosed ducks surviving 30 days
[d]Zn-dosed ducks surviving < 30 days

Table 9. Mean ± SE (CV) weight of kidneys and the mean percentage it contributed to total body weight in game-farm mallards dosed with 6 No. 4 Zn or Fe shot[a]

Sex	Dose	Mean Weight (g)	Mean % of Body Weight
M	Zn[b]	6.7 ± 0.4 (0.3)	0.7
M	Fe	5.4 ± 0.1 (0.1)	0.5
F	Zn[b]	6.5 ± 0.4 (0.3)	0.9
F	Fe	5.1 ± 0.2 (0.2)	0.5
M	Zn_{30}[c]	5.6 ± 0.3 (0.2) (n=11)	0.5 (n=11)
M	$Zn_{<30}$[d]	8.1 ± 0.4 (0.4) (n= 9)	1.0 (n= 9)
F	Zn_{30}[c]	4.8 ± 0.2 (0.1) (n= 4)	0.5 (n= 4)
F	$Zn_{<30}$[d]	6.9 ± 0.4 (0.2) (n= 16)	1.1 (n= 16)

[a]n= 20 for each group unless otherwise specified
[b]includes Zn-dosed ducks surviving < 30 days
[c]Zn-dosed ducks surviving 30 days
[d]Zn-dosed ducks surviving < 30 days

Table 10. Mean ± SE (CV) weight of gonads and the mean percentage they contributed to total body weight in game-farm mallards dosed with 6 No. 4 Zn or Fe shot[a]

Sex	Dose	Mean Weight (g)	Mean % of Body Weight
M	Zn[b]	4.8 ± 1.5 (1.4)	0.4
M	Fe	5.8 ± 1.2 (0.9)	0.5
F	Zn[b]	0.3 ± 0.0 (0.4)	0.1
F	Fe	0.7 ± 0.2 (0.2)	0.1
M	Zn_{30}[c]	8.1 ± 2.3 (0.9) (n=11)	0.7 (n=11)
M	$Zn_{<30}$[d]	0.7 ± 0.2 (0.7) (n= 9)	0.1 (n= 9)
F	Zn_{30}[c]	0.4 ± 0.1 (0.2) (n= 4)	0.0 (n= 4)
F	$Zn_{<30}$[d]	0.3 ± 0.0 (0.4) (n= 16)	0.1 (n= 16)

[a]n= 20 for each group unless otherwise specified
[b]includes Zn-dosed ducks surviving < 30 days
[c]Zn-dosed ducks surviving 30 days
[d]Zn-dosed ducks surviving < 30 days

Table 11. Mean ± SE (CV) weight of gizzard and the mean percentage it contributed to total body weight in game-farm mallards dosed with 6 No. 4 Zn or Fe shot[a]

Sex	Dose	Mean Weight (g)	Mean % of Body Weight
M	Zn[b]	23.5 ± 1.6 (0.3)	2.4
M	Fe	29.2 ± 0.5 (0.1) (n=19)	2.6
F	Zn[b]	17.2 ± 1.3 (0.3)	2.4 (n= 18)
F	Fe	27.2 ± 0.8 (0.1)	2.8
M	Zn_{30}[c]	29.0 ± 1.4 (0.2) (n=11)	2.6 (n=11)
M	$Zn_{<30}$[d]	16.9 ± 0.5 (0.1) (n= 9)	2.1 (n= 9)
F	Zn_{30}[c]	26.8 ± 1.8 (0.1) (n= 4)	2.8 (n= 4)
F	$Zn_{<30}$[d]	14.8 ± 0.7 (0.2) (n= 16)	2.3 (n= 16)

[a]n= 20 for each group unless otherwise specified
[b]includes Zn-dosed ducks surviving < 30 days
[c]Zn-dosed ducks surviving 30 days
[d]Zn-dosed ducks surviving < 30 days

Table 12 . Mean hematocrit ± S.E. (CV) of 6-8 month-old male and female game-farm mallards dosed with 6 No. 4 Zn or Fe shot.[a]

Dose	Sex	Hematocrit (% PCV) Day 0	Day 15[b]	Day 30[c]
Zn	M	44.65 ± 0.58 (0.06)	40.87 ± 2.81 (0.22) (n= 15)	47.64 ± 0.79 (0.06) (n= 15)
	F	46.15 ± 0.02 (0.06)	32.46 ± 3.19 (0.35) (n= 13)	44.25 ± 0.63 (0.03) (n= 4)
Fe	M	45.15 ± 0.60 (0.06)	46.60 ± 0.79 (0.08)	46.80 ± 0.46 (0.04)
	F	44.80 ± 0.58 (0.06)	44.60 ± 0.49 (0.05)	45.95 ± 0.61 (0.06)

[a] n= 20 unless otherwise specified
[b] includes ducks surviving < 15 days
[c] includes ducks surviving > 15 and < 30 days

Table 13. Mean percent change in hematocrit ± SE (CV) between Days 0 and 15 in 6-8 month old, male game-farm mallards dosed with 6 No. 4 Zn or Fe shot.[a]

Dose	Percent Change Day 0 - 15
Zn[b] (n=15)	- 8.9 ± 6.3 (2.8)
Fe	3.2 ± 1.1 (1.6)

[a] n= 20 unless otherwise specified
[b] Zn-dosed ducks surviving at least 15 days

Table 14. Mean percent change in hematocrit ± SE (CV) between Days 0 and 15 in 6-8 month old, female game-farm mallards dosed with 6 No. 4 Zn or Fe shot.[a]

Dose	Percent Change Day 0 - 15
Zn[b] (n=13)	- 29.6 ± 6.7 (0.8)
Fe	- 0.2 ± 1.5 (33.0)

[a] n= 20 unless otherwise specified
[b] Zn-dosed ducks surviving at least 15 days

Table 15. Mean percent change in hematocrit ± SE (CV) between Days 0 and 30 in 6-8 month old, male game-farm mallards dosed with 6 No. 4 Zn or Fe shot.[a]

Dose	Percent Change Day 0 - 15
Zn[b] (n=11)	- 6.3 ± 1.8 (1.0)
Fe	3.9 ± 1.3 (1.5)

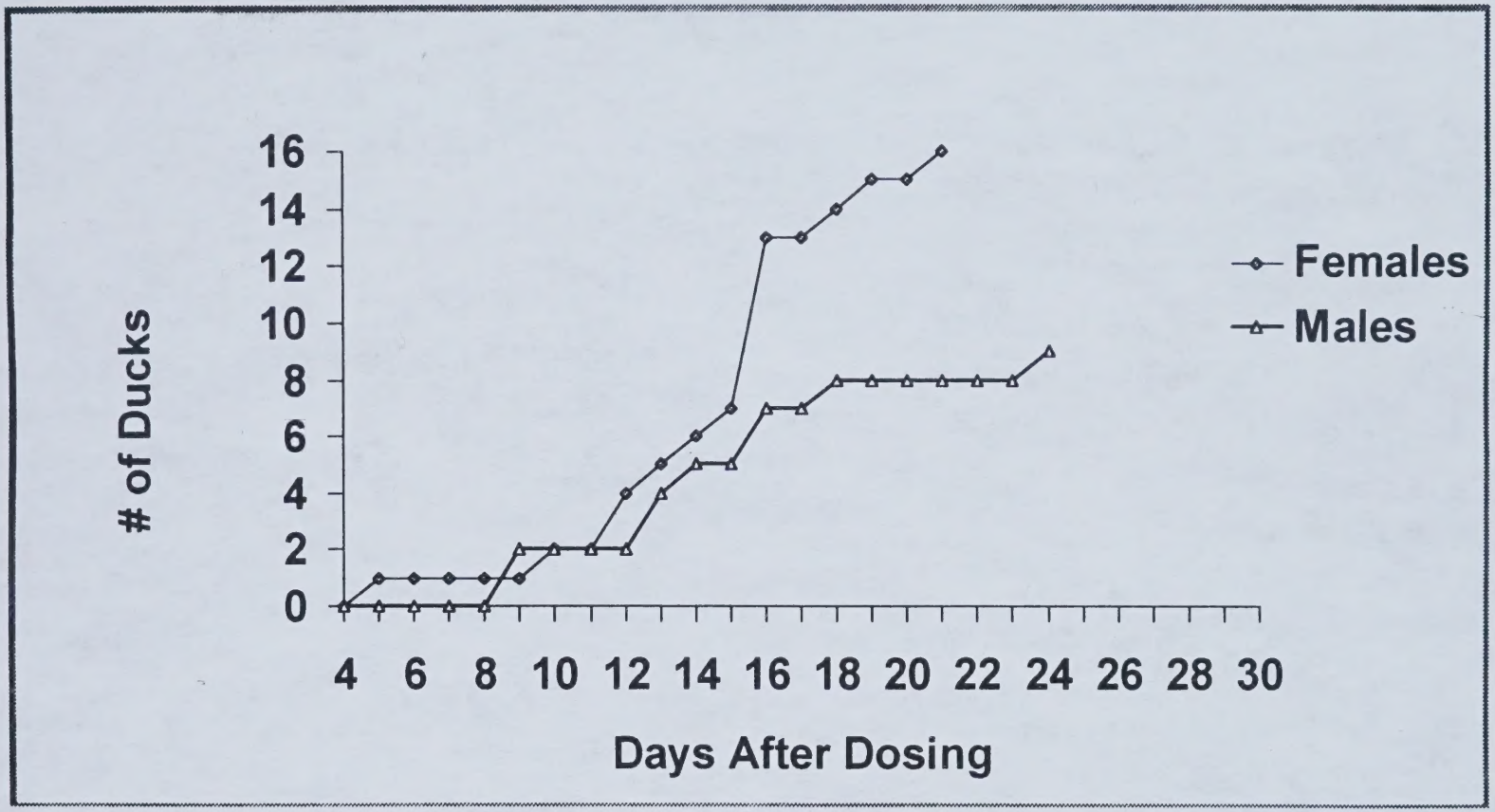
[a] n= 20 unless otherwise specified
[b] Zn-dosed ducks surviving to 30 days

Table 16. Mean percent change in hematocrit ± SE (CV) between Days 0 and 30 in 6-8 month old, female game-farm mallards dosed with 6 No. 4 Zn or Fe shot.[a]

Dose	Percent Change Day 0 - 15
Zn[b] (n=4)	- 2.8 ± 4.0 (2.9)
Fe	2.7 ± 1.4 (2.2)

[a] n= 20 unless otherwise specified
[b] Zn-dosed ducks surviving to 30 days

CUMULATIVE DEATHS



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